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GOVERNMENT OF INDIA
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MINISTRY OF RAILWAYS
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Guidelines

For

Blanket Layer Provision

On

Track Formation

With Emphasis On

Heavy Axle Load Train Operation

Report No. RDSO/2007/GE : 0011

July 2007

Geo-technical Engineering Directorate
Hkw&r duhdh bathfu;jh funs'kky;
Research Designs & Standards Organisation
vuqla/kku vfHkdYi vkSj ekud laxBu
Lucknow – 226011
y[kuÅ & 22601

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SYNOPSIS

Indian Railways have entered the era of running of heavier axle load trains and are planning to construct 'Dedicated Freight Corridors'. Provision of blanket layer on top of formation is essential to construct stable formation, suitable for running heavy axle loads. Under such circumstances, there is need to standardise specifications and thickness of blanket layer to cater heavy axle load train operation.

This report has been prepared on the basis of outcome of the two in-house studies done in Geo-technical Engineering Directorate during 2007-08. One study is titled as 'Study of Higher Axle Load on Railway Formation' vide report no. RDSO/2007/GE-1010 : April 2007. This report mainly reviews design methodologies adopted on various world railway systems, e.g. American Railways, European Railways, Australian Railways etc. The second report is field study report, titled 'Study Of Ballast Penetration with Different Types Of Soils on Indian Railways' vide report no. RDSO/2007/GE : SR-0008 : July 2007.

The present document includes the specifications & thickness of blanket layer provided on the formation, suitable for heavy axle load train operations with incorporation of new features like geo-synthetics, two layered concept of blanket layer & layer of prepared sub-grade, which also specifies additional filter criteria & Los Angles Abrasion Value for blanket material. The existing instructions available on the subject in various Guidelines will get superseded by the provisions contained in this document.

The proposed thickness & specifications of blanket material alongwith design methodology of formation design may get revised subsequently on the basis of outcome from research projects being undertaken by Geo-technical Engineering Directorate of RDSO in collaboration with various Centres of Excellence.

PREFACE

This report is based on literature survey, experience gained and field observations done by RDSO. The views expressed in the document are subject to modification from time to time in light of future developments on the subject.

(Alok Kumar)
Executive Director/Geo-technical Engineering
Research Designs And Standards Organisation, Lucknow

1.0 INTRODUCTION

Over the years, increase in traffic and speeds have placed a greater structural demand on conventional track, constructed initially to cater for much lighter traffic. Gradual improvement to track support system however, remained confined to track superstructure, i.e. rails, sleepers, fastening etc. The sub-structure below sleeper level remained practically unchanged.

Provision of blanket on top of formation has become a necessity. Due to non-provision of blanket, large stretches of track on Indian Railways are having speed restrictions, costly maintenance practices as well have become an impediment in the introduction of higher speed and higher axle loads.

Traditionally, blanket layer of single specified material, as thick as 1 metre, was recommended, which becomes very costly & difficult to provide. Under the circumstances, two layer blanket system and use of geo-synthetics have been studied for use in top portion of formation from strength as well as economic considerations.

2.0 HISTORICAL DEVELOPMENTS ON BLANKET LAYER

2.1 Provision of blanket layer on Indian Railways was stipulated in August-1978 for the first time in the 'Guidelines for Earthwork in Embankments & Cuttings of New Construction, Doubling & Conversion Projects', where it was mentioned that "the depth of blanket should normally be about 30cm in ordinary clayey soil. However, if formation soil is weak, a thicker layer upto 60cm may be necessary depending on the shear properties of the formation soil." However, no technical justification is available for this stipulation.

2.2 In subsequent reviews, "Guidelines for Earthwork in Railway Projects" was issued in May 1987, where the mention was - "inspite of the present state of knowledge about the soil behaviour under repetitive loading, it is not possible to account for the drop of strength under a particular traffic density and wheel loads. In the absence of a sure method of working out thickness of blanket, which would take into account all the factors and keeping the future growth of traffic densities and axle loads as well as the experience with already existing trouble-some formations, one metre thick blanket layer of approved quality should be laid in case of all new constructions".

2.3 This subject-matter was further reviewed and as advised by Railway Board vide their letter no. 90/CEII/SF/9, dated 12.4.1991, Para-4.4 was revised and subsequently included in the "Guidelines for Earthwork–1987 as under :

"Blanket and Sub-ballast :

Blanket : Blanket may be required over the formation where the soil is of poor quality, rainfall is heavy and traffic density is high, as the absence of blanket in such cases can lead to problems in service, such as swelling or heaving of formation. Whether the blanket should be provided in a particular length and if so, its thickness (which should not be less than 30cm) should be decided by the Chief Engineer (Const.), in-charge of the project, duly taking into account the type of soil, rainfall and density of traffic and other factors relevant to the site conditions.

Sub-ballast : In order to reduce the effect of loads transmitted to formation through ballast and to guard against the possibility of ballast penetration into the formation, it may be desirable to provide a sub-ballast of 15cm depth below the ballast layer. The sub-ballast may comprise of locally available coarse material so as to serve as an effective medium between the formation earth and ballast stone. The need to provide this sub-ballast may be decided by Chief Engineer (Const.) in-charge of the project".

2.4 This para was corrected vide Correction Slip no. 2 to the above mentioned Guidelines and instructions regarding thickness of blanket were again modified in terms of Railway Board's letter no. 94/CE-II/MB/2, dated 10.12.98. Perusal of these developments since 1978 to 1991 indicates that :

(i) Based on experience, necessity was felt for provision of blanket and/or sub-ballast.

(ii) Assessment of thickness of blanket material was left on individual judgment, leaving scope for wide variation.

2.5 Literature survey was carried out to know the practices being followed in World Railways. Accordingly, "State-of-the-Art-Report on Sub-grade Stress and Design of Track Structure (C-271) June-1993" was published. In this report, it was suggested that -

(i) For sub grades consisting of clayey soils, total depth of ballast & blanket can be worked out using Design Chart (taken from ORE D-7I, RP12) for different axle loads and threshold strength of soil. Threshold stress of soil can be assumed as 45% of UCC strength and

(ii) For sub-grades consisting of other than clayey soils, depth of construction will be designed based on Young's Modulus of Elasticity, i.e. 'E-values' of sub-grade soils, as done on European Railways.

(iii) It was also concluded that in case of cohesive sub-grades of important lines carrying bulk of the traffic both passenger and goods, there is need of blanket of coarse grained material of about 100 cm thickness to keep the maintenance efforts within reasonable limits.

2.6 Further, in the year 2000, Railway Board nominated a committee of four SAG officers who had earlier served Geo-technical Engineering Directorate of RDSO to make recommendation for blanketing on railway formation. In August 2001, the committee recommended provision of blanket thickness based on various soil types which has subsequently been adopted in RDSO's revised 'Guidelines For Earthwork in Railway Projects : July 2003'.

3.0 FUNCTIONS OF BLANKET LAYER

3.1 Role :

Blanket is a layer of coarse grained material between ballast and sub-grade, spread over entire width. On some other railway systems of the world, this layer is also called as sub-ballast. The important roles are :

1. Improving the bearing capacity by modifying the stiffness and achieving a better distribution of transmitted loads on the sub-grade soil, thus preventing ballast penetration into the formation.
2. Reduction of induced stresses on the top of sub-grade to a tolerable level.
3. To prevent mud pumping and fouling of ballast by upward migration of fine particles from the sub-grade.
4. To prevent damage of sub-grade by ballast.
5. Shedding surface water from the ballast and drain away from the sub-grade.
6. Protection of sub-grade against erosion and climatic variations.

3.2 Functions :

A blanket layer fulfils following important functions :

3.2.1 Primary Function :

Stress Reduction Function - It reduces the traffic induced stresses at the bottom of ballast layer to a tolerable limit on top of sub-grade. This function must be fulfilled to avoid track foundation failures.

3.2.2 Secondary Function :

i) Separation Function : It prevents penetration of ballast into sub-grade and also prevents upward migration of fine particles from sub-grade into ballast.

ii) **Drainage Function :** It should intercept water coming from ballast away from sub-grade and at the same time, permit drainage of water that is flowing upward from the sub-grade.

iii) **Prevention of Mud Pumping :** It prevents mud pumping by checking attrition of sub-grade particles by ballast.

The quality of blanket material should be such that it is able to carry out the above functions satisfactorily. Various requirements to achieve above objectives are discussed in following paragraphs.

3.3 Requirements To Achieve Functions -

One of the most important functions of provision of ballast layer under sleeper is to reduce stresses. It is neither economical nor desirable from stability considerations to provide the entire stress reduction by ballast depth alone. Hence, blanket layer of adequate thickness is required to be provided to reduce the induced stresses to an acceptable level at the top of sub-grade without undergoing its self failure.

For achieving this requirement, blanket material serves as a structural material, which should have adequate strength under dynamic loads and vibrations, high resilient modulus, reasonable plastic strain accumulation characteristics under repeated wheel loads etc. Therefore, the material must be permeable enough to avoid any significant positive pore pressure build-up under repeated load. It must consist of durable particle and should not be sensitive to moisture content. It should also resist break-down and abrasion from the cyclic stresses produced by the train loading.

From the studies of the practices followed on advanced Railway Systems, it emerges that the above demands are fulfilled, if specifications of blanket material fulfil following criteria :

i) The material is coarse grained, hard and well graded.

ii) Maximum percentage of fines (particle size less than 75 microns) present in blanket material is limited upto 10% to 12%. Allowing more fines in blanket material will lead to plasticity behaviour of blanket material. Also, a minimum percentage of fines are required to give binding property to the blanket material so that erosion of blanket material does not take place due to high intensity rainfall.

iii) Material does not liquefy under vibrations caused by train movement and, therefore, is well graded.

It can be seen that the above requirements have been specified so that the blanket material is cohesion-less with adequate gradation and permeability. If more fines are permitted in blanket material, then the material will start behaving like a cohesive material, having different strength behaviour than cohesion-less material. Such materials are not able to dissipate pore water pressure under repeated cyclic loading of the trains, thus resulting into failure of blanket material.

4.0 EXISTING PROVISIONS OF BLANKET ON INDIAN RAILWAYS

4.1 Unsuitable Soils for Construction :

Soils to be normally avoided are :

a) Organic clays, organic silts, peat, chalks, dispersive soils, poorly graded gravel and sand with uniformity coefficient (Cu) less than 2,

b) Clays and silts of high plasticity (CH & MH) in top 3m of embankment.

4.2 Depth of Blanket Layer :

Depth of blanket to be provided for axle loads upto 22.5t for different types of sub-grade soils (minimum top one metre thickness) has been given as under :

(In case more than one type of soil exists in top one metre, soil requiring higher thickness of blanket will govern)

a) Following soils shall not need any blanket :

- Rocky beds except those, which are very susceptible to weathering, e.g. rocks consisting of shales and other soft rocks, which become muddy after coming into contact with water.
- Well graded Gravel (GW)
- Well graded Sand (SW)
- Soils conforming to specifications of blanket material.

Note : Soils having grain size curve lying on the right side of the enveloping curves for blanket material like cobbles and boulders may/may not need blanket. In such cases, need of blanket and its design should be done in consultation with RDSO.

b) Following soils shall need minimum 45cm thick Blanket :

- Poorly graded Gravel (GP) having Uniformity Coefficient more than 2.
- Poorly grade Sand (SP) having Uniformity Coefficient more than 2.
- Silty Gravel (GM)
- Silty Gravel – Clayey Gravel (GM – GC).

c) Following soils shall need minimum 60cm thick Blanket :

- Clayey Gravel (GC)
- Silty Sand (SM)
- Clayey Sand (SC)
- Clayey Silty sand (SM-SC)

Note : The thickness of blanket on above type of soils shall be increased to 1 metre, if the plasticity index exceeds 7.

d) Following types of soils shall need minimum 1 metre thick Blanket :

- Silt with low plasticity (ML)
- Silty clay of low plasticity (ML-CL)
- Clay of low plasticity (CL)
- Silt of medium plasticity (MI)
- Clay of medium plasticity (CI)
- Rocks which are very susceptible to weathering

Soils having fines passing 75 micron sieve between 5 & 12%, i.e. for soils with dual symbol, e.g. GP-GC, SW-SM, etc., thickness of blanket should be provided as per soil of second symbol (of dual symbol). For example, if the soil of the sub-grade over which the blanket is to be provided is classified as GP-GC, blanket depth for GC type of soil, i.e. 60 cm is to the provided.

Use of geo-synthetics can be considered at places where it is economical to use in combination with blanket as it reduces the requirement of thickness of blanket. It may be particularly useful in cases of rehabilitation of existing unstable formation and in new construction where availability of blanket material is scarce. Use and selection of geo-synthetics should be done in consultation with RDSO.

For heavier axle load traffic above 22.5t and upto 25t & above 25t upto 30t, additional blanket thickness of 30cm & 45cm respectively, over and above as given above, of superior quality material, shown as upper blanket layer in Sketch "B", should be provided.

4.3 Specifications of Blanket Material :

Blanket material should generally conform to following specifications :

a) It should be coarse, granular and well graded.

b) Skip graded material is not permitted.

c) Non-plastic fines (particles of size less than 75 micron) are limited maximum to 12%, whereas plastic fines are limited maximum to 5%.

d) The blanket material should have particle size distribution curve more or less within the enveloping curves shown in Sketch-B of RDSO document 'GE: G-1, July 2003'. The material should be well graded with Cu and Cc as under :

- Uniformity Coefficient Cu = D_{60}/D_{10} > 4 (preferably > 7)
- Coefficient of Curvature $C_C = (D_{30})^2 / D_{60} \times D_{10}$ should be within 1 and 3.

e) The material for upper blanket layer, required for heavier axle load, shall be well-graded sandy gravel or crushed rock within the enveloping curves for upper blanket layer as shown in Sketch-B of RDSO document 'GE: G-1, July 2003'.

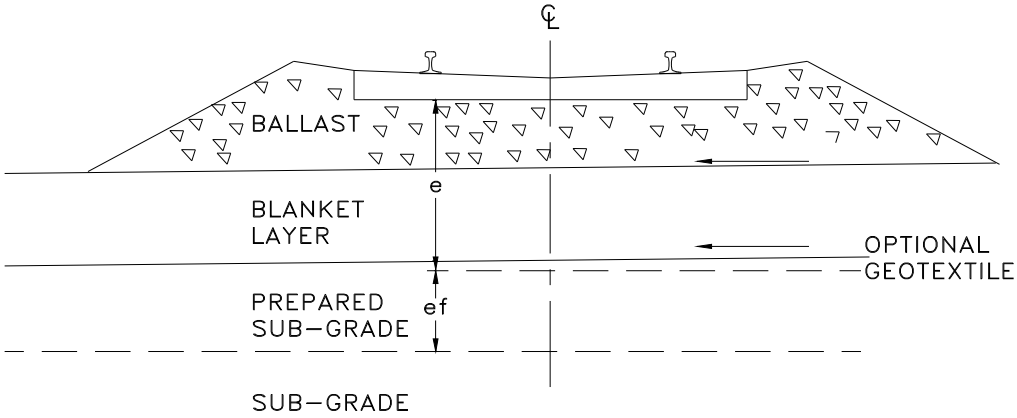
5.0 BENCHMARKING - PROVISIONS OF BLANKET IN OTHER RAILWAY SYSTEMS

5.1 European Railways (UIC) -

5.1.1 Provisions :

As per UIC code 719 R, 1994 minimum thickness (e) of track bed layers is given by the formula –

e = E + a + b + c + d + f + g as per figure below :



Where,

e = Total depth of ballast & blanket
E = Factor depending upon **quality class of soil** used in prepared subgrade
a = Factor depending on UIC groups based on **GMT**
b = Factor depending on **type & length of sleeper**
c = Factor depending on different **working conditions** on existing lines
d = Factor depending on **axle load** of hauled vehicle
f = Factor depending on **speed of train**
g = Factor depending on inclusion of **geo-textile** based on quality class of prepared sub-grade.

The values of the above factors, as given in the UIC-719R code are as under :

E = 0.70 m For QS1 soils used as prepared sub-grade
E = 0.55 m For QS2 soils used as prepared sub-grade
E = 0.45 m For QS3 soils used as prepared sub-grade
(Thickness of prepared sub-grade varies from 35 cm to 50 cm)

a = 0 For UIC groups 1 & 2 (or lines where speed>160 km for all UIC groups)
a = -0.05m For UIC group 3 & 4
a = -0.10m For UIC groups 5, 6 & 7, 8, 9 with passengers
a = -0.15m For UIC groups 7, 8, 9 without passengers

b = 0 For wooden sleepers of length 2.60m
b = (2.50-L) / 2 For concrete sleepers of length L (b in m, L in m)

c = -0.05 m For difficult working condition

d = 0 For 200 kN axle load
d = 0.05 m For 225 kN axle load
d = 0.12 m For 250 kN axle load

f = 0 For speed < 160 kmph
f = 0.05 m For speed > 160 kmph for sub-grade of QS_2 class
f = 0.10 m For speed > 160 kmph for sub-grade of QS_1 class

g = + Track bed must include a geotextile for soil of QS_1 & QS_2 class

Soil Quality Class QS_0, QS_1, QS_2 & QS_3 are defined in UIC Code are as under :

Soil Type (Geo-technical Classification)		Soil Quality Class
0.1	Organic soils	QS_0
0.2	Soft soils containing more than 15% fines (1) with high moisture content: therefore unsuitable for compaction.	
0.3	Thixotropic soils (2) (e.g. quick clay)	
0.4	Soils containing soluble material (e.g. rock salt or gypsum)	
0.5	Contaminated ground (e.g. industrial waste)	
0.6	Mixed material/organic soils (2)	
1.1	Soft soils containing more than 40% of fines (1) (except for soils classified under 0.2)	QS_1
1.2	Rocks which are very susceptible to weathering, e.g. : - Chalk with ρ_d<1.7t/m^3 and high friability - Marl - Weathering shale	
1.3	Soils containing 15% to 40% of fines (1) (except for soils classified under 0.2)	QS_1 (3)
1.4	Rocks which are moderately susceptible to weathering, e.g. - Chalk with ρ_d <1.7t/m^3 and low friability - Un-weathered shale	
1.5	Soft rock e.g. Micro-deval wet (MDE)>40 and Los Angles (LA) > 40	
2.1	Soils containing from 5 to 15% of fines (1)	QS_2 (4)
2.2	Uniform soil containing less than 5% of fines (1) (Cu ≤ 6) Moderate hard rock, e.g. : If 25<MDE≤40 and 30< LA≤40	
3.1	Well graded soils containing less than 5% of fines (1) Hard rock, e.g. : If MDE ≤25 and LA ≤ 30	QS_3

i. These percentages are calculated from particle size distribution analysis undertaken on material passing a 60 micron sieve. The percentages indicated have been rounded down (particles vary slightly vary from one Railway to another); they may be increased by upto 5% if sufficiently representative number of samples are taken.

ii. Certain Railways sometimes include these soils in quality class QS_1.

iii. These soils can come under quality class QS_2 if the hydro-geological and hydrological conditions are good.

iv. These soils can come under quality class QS_3 if the hydro-geological and hydrological conditions are good.

5.1.2 Specifications of Blanket Material :

i) Blanket material must be a well graded sandy-gravel material (Cu>6 and Cc between 1 & 3).

ii) It should be sufficiently durable e.g. Los Angeles value less than 20 or 25.

iii) Some railways require sandy gravel to contain at least 30% of crushed stone.

iv) It should satisfy Terzaghi Filter criteria with sub-grade soil.

v) If blanket layer is in contact with fine grained (silty or clayey) sub-grade, it should have about 20% fine sand (particle size less than 0.2 mm).

5.2 Practices of American Railways -

American Railway Engineering and Maintenance-of-way Association (AREMA) Manual of Railway Engineering 2002 recommends use of 12 inches ballast and 12 inches sub-ballast on main track. Use of soils with Plasticity Index > 12 for a depth of 4 feet below sub-ballast should be avoided, if possible.

5.2.1 AREMA Specification for Sub-ballast :

i) Material to be used is similar to highway bases and sub-bases such as crushed stone, natural or crushed gravel, natural or manufactured sands, crushed slag etc.

ii) Sub-ballast shall be granular material so graded as to prevent penetration into sub-grade and penetration of ballast into sub-ballast zone.

iii) Filter principles should be used in drainage to the grading of sub-grade.

iv) Maximum size of sub-ballast should not exceed maximum size of ballast.

v) Not more than 5% of the sub-ballast should pass the no. 200 sieve (60 micron).

5.2.2 Filter Criteria Requirement :

The two resulting separation gradation for drainage filter criteria are :

- D_{15} (filter blanket) < 5 x D_{85} (sub-grade)
- D_{50} (filter blanket) < 25 x D_{50} (sub-grade) (Ratio of D_{50} in range of 9 to 30)

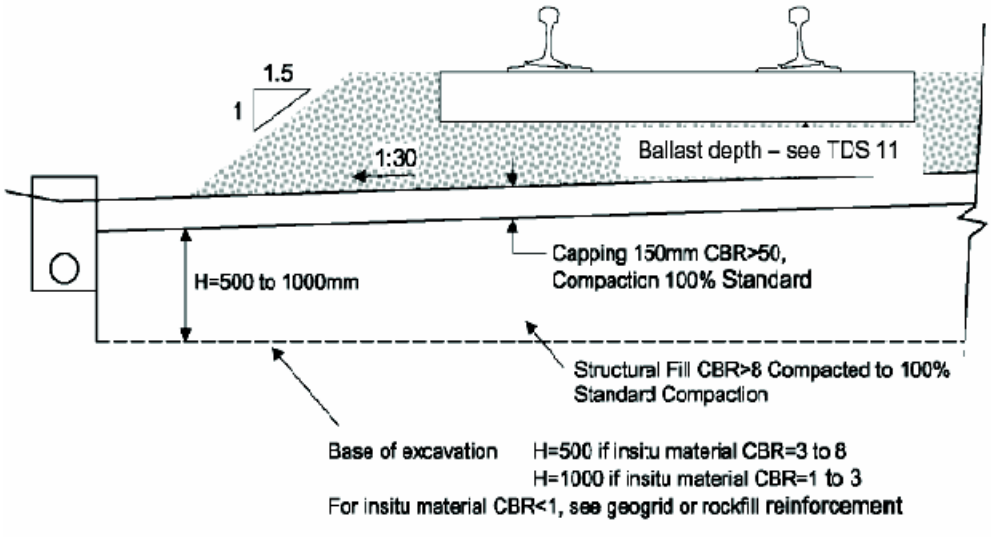
Criteria ensures blocking the upward movement of particles at the coarsest end of protected soil (D85).

Additional criteria to ensure adequate permeability to drain sub-grade -

- D_{15} (filter) < 20 x D_{15} (sub-grade) (Ratio of D_{15} in range of 6 to 18)

5.3 Blanket/ Capping Layer In Australian Railways

Australian Railway Track Corporation provides 15 cm blanket/capping material over 0.5 m of sub-grade having CBR values more than 8 or over 1 m of sub-grade if its CBR is in range of 3 to 8 as shown in Figure below :



Note: Construction using full depth of capping material instead of two materials will reduce total depth by about 30%

5.3.1 General Requirements of Blanket Material :

Material proposed for capping shall be a well graded natural or artificially blended gravel/soil. It shall have sufficient fines to permit it to be compacted to high densities by static or vibratory steel-tyred rollers or by ballasted pneumatic-tyred rollers. Materials such as natural ridge gravel free from vegetable matter, ripped sandstones with low clay content and crushed and blended tough, durable rock or slag, have been found to meet material properties of this specification.

5.3.2 Material Properties :

Natural gravels may be combined to provide material which conforms to this specification. Crushed rock shall include such added material as necessary for the combined material to satisfy the requirements of this specification.

5.3.3 Particle Size Distribution :

Material shall be well graded with typical particle size distribution as follows :

AS Sieve	Percentage Passing Nominal Size (20mm)
53 mm	100
37.5 mm	100
26.5 mm	100
19.0 mm	95-100
9.5 mm	-
4.75 mm	-
2.36 mm	30-80
0.075 mm	6-10

5.3.4 Atterberg Limits :

- Liquid Limit : Maximum 30 (35 for arid areas)
- Plastic Limit : Maximum 20
- Plasticity Index : 2 -10 (2 -15 for arid areas)
- Linear Shrinkage : Maximum 3%

5.3.5 Maximum Dry Density : Minimum 2.0 t/cum

5.3.6 Soaked CBR : Minimum 50%, determined on material compacted to 95% (min.) of Maximum Dry Density

6.0 FIELD STUDY ON BALLAST PENETRATION IN SUB-GRADE OF FORMATION ON INDIAN RAILWAYS – THE OBSERVATIONS

6.1 A field study was undertaken by Geo-technical Engineering Directorate of RDSO to assess the performance of formations where blanket material has been and has not been provided. In this effort, behaviour of new track formations on projects of new lines, doublings and gauge conversion on various Zonal Railways has been studied. Track attentions, ballast penetration, GMT and several other important data have been collected during monitoring of track formations.

6.2 RDSO teams collected data for total 21 projects on various Zonal Railways, out of which 10 sections (44 nos. of observations) were blanketed sections and 11 sections (54 nos. of observations) were non-blanketed sections of different construction projects on Indian Railways.

6.3 Data collected have been compiled & analyzed and a report on 'Study Of Ballast Penetration with different Types Of Soils on Indian Railways' vide Report No. RDSO/ 2007/GE : SR-0008 : July 2007 has been prepared. Based on analysis of data collected, main conclusions of the report are :

6.3.1 It is observed from the study of data collected that provision of blanket on sub-grade is necessary as it reduces track maintenance efforts and ballast penetration in formation gets reduced. Thus, it reduces cost of track maintenance and results in smooth running of fast and heavier traffic.

6.3.2 It has been observed that ballast penetration and number of track attentions are almost nil even on sub-grades constructed with fine-grained soils where thickness of blanket provided was less than the required thickness as prescribed in *'Guidelines For Earthwork In Railway Projects, GE : G-1, July 2003'*. Therefore, earlier recommended thickness of blanket material based on type of sub-grade soil can be reduced substantially.

6.3.3 Slight deviation to the prescribed values of Uniformity Coefficient (Cu) for blanket material can also be permitted, as is evident from the study.

6.3.4 Slight deviation to the prescribed values of Coefficient of Curvature (Cc) for blanket material can also be permitted, as is evident from the study.

6.3.5 It is observed that ballast penetration in sub-grades constructed with fine-grained soils (Soils having more than 50% particles passing through 75 micron I.S. sieves) is more compared to penetration in formations constructed with coarse-grained soils.

6.4 **Conclusions** of this field study clearly indicate that blanket layer is required even for present axle loads, as ballast penetration has been observed on all the formations where blanket has not been provided and more importantly, there is good scope of reduction in presently prescribed thickness of blanket layer on sub-grade top on Indian Railways with suitable revisions in the existing provisions on the subject in RDSO's document - 'Guidelines For Earthwork In Railway Projects, GE : G-1, July 2003'.

7.0 TWO LAYERS SYSTEM OF FORMATION DESIGN VIS-À-VIS BLANKET MATERIAL

7.1 From the observations of provisions of various World Railway Systems, it is evident that there is requirement & practice of not allowing poor soils in top one metre thickness of sub-grade and strengthening of about top 1 metre of formation is necessary with material of superior quality like blanket material.

7.2 As on date on Indian Railways, one metre blanket layer is being provided with single type of material having superior specifications, which many a times is available at very high cost, thus it proves to be uneconomical. Also, dispensation to its provisions is normally granted by Railway Board on the requests of Zonal Railways.

7.3 It has also been observed that AREMA recommends for not using soil having plasticity index more than 12 in top 4 feet thickness of sub-grade, UIC provides layer of prepared sub-grade of 35 cm to 50 cm of better material and Australian Railways provide 50 cm to 1 metre of sub-grade having CBR value more than 8.

Similar to AAR, UIC or Australian Railways, total requirement of blanket layer can be provided with two types of materials, upper layer which is in contact of ballast can be of superior quality and lower layer which is in contact with sub-grade can be with specifications such that poor material should not appear in top portion of sub-grade.

7.4 The design method given in AAR report no. R-898, October 1996 seems to be quite a rational method, which determines thickness of granular layer based on Axle Load, Speed, GMT, Soil types etc. It requires field measurement of soil parameters and design calculations every time when new formation is required to be constructed. However, provisions regarding sub-ballast layer given in AREMA Manual do not seem to be based on the method given in AAR Report no. R-898; therefore, these are not being presently considered for adoption on Indian Railways.

7.5 UIC provisions as given in UIC Code 719 are systematic & streamlined; covering all aspects, e.g. Axle Load, Speed, GMT, Sub-grade Type etc. Recommendations have been made in UIC Code 719 for axle loads in range of 20 to 25 tonne. Since formation design for Heavy Axle Load Freight Corridors is to be done for 32.5 tonne axle loads, extrapolation has been done for 30 tonne and 32.5 tonne axle loads from UIC provisions. These are shown in Sketch-1. Keeping in view the other relevant factors, such as Axle Loads, Speed, GMT, Sleeper Length suitable for Indian Railways, detail calculations of blanket thickness for various soils, based on UIC practices have been carried out and are illustrated in Annexure-1.

7.6 Proposed thickness of blanket material & prepared sub-grade and type of sub-grade alongwith soil types as per IS Classification belonging to various 'Soil Category SQ' have been given in Table-2 & also shown in Sketch-2. Soil Categories SQ1, SQ1 & SQ3 have been modified slightly from UIC practices to suit Indian conditions & BIS Classification system.

7.7 Prepared sub-grade should be preferable with SQ3 soils, having fines less than 12%. If prepared sub-grade is of SQ1 or SQ2 type soils, geo-textile layer shall be provided at junction of bottom of blanket layer & top of prepared sub-grade.

7.8 Proposed typical profile for Heavy Axle Load Freight Corridor, showing thickness of prepared sub-grade, blanket layer over different types of sub-grade has been illustrated in Sketch-4.

7.9 The recommended thickness and specifications of blanket material are based on UIC document which is for axle loads upto 25 T. Blanket specifications suitable for further higher axle loads will require more study/visit and experience of foreign railway systems, where 30T or higher axle load trains are running.

8.0 ABRASION VALUE CONSIDERATION FOR BLANKET MATERIAL

8.1 On Indian Railways, specifications of blanket material are defined in terms of particle size gradation, maximum percent of fines, Uniformity Coefficient Cu and Coefficient of Curvature Cc. However, these specifications do not ensure sufficient hardness of the material as blanket material is subjected to high stresses imposed by train loads. BIS Code IS : 2386 Part IV-1963 describes the Los Angles Abrasion Value as a measure of resistance to wear.

8.2 Para 2(i) of Annexure–II of 'Guidelines for Earthwork in Railway Projects, May 1987' specifies that blanket material 'should be coarse and granular.' However, vide Railway Board's letter no. 95/W1/Genl/0/39, dated 09.10.96, this para was amended as - 'Blanket material should be coarse, granular and from hard rock.' Later, this amendment was not included in revised 'Guidelines for Earthwork in Railway Projects, GE: G-1, July 2003'; probably due to the reason that hardness of the material is not quantified and may lead to ambiguity to field engineers.

8.3 UIC Code 719 R, 1994 mentions that blanket material should be sufficiently durable and its Los Angles Abrasion value should be less than 20 or 25.

8.4 American Railways, as per AREMA Manual 2002, do not specify any value as a measure of hardness. However, Para-9.1 of "The ASTM D1241 Standard Specifications for Aggregate Layers for Roads" in the reference book on 'Track Geo-technology and Sub-structure Management' by E. T. Selig is used as a basis for sub-ballast by North American Railroads.

The coarse aggregate (>2mm) must have maximum loss in the LAA test using ASTM C131 of 50. Generally higher LAA value is acceptable for sub-ballast than for ballast because the traffic stresses are lower and the smaller size and broader gradation makes particle contact stresses much lower than in ballast.

8.5 As per 'Specifications of Track Ballast, GE : IRS-1, June 2004, maximum abrasion value of 30 has been specified which is relaxable upto 35 in exceptional cases by CTE & CAO(C) on techno-economic grounds.

In order to avoid chance of soft material to be selected as blanket material, suitable LA Abrasion value as a measure of hardness/wear resistance should be specified. Based on above discussion, blanket material with maximum Los Angles Abrasion value of 40 may be suitable & is being prescribed for adoption on Indian Railways.

9.0 SPECIFICATIONS OF MATERIAL FOR BLANKET LAYER

9.1 Specifications of the material for blanket layer over prepared sub-grade should be such that it is well-graded sandy gravel layer of adequate hardness. Particles size gradation curve should be more or less within Enveloping Curves of blanket material as shown in Sketch-3 & Grading Percentages within the range given in Table-1 and should also have following **criteria** satisfied :

i) Cu > 7 and Cc between 1 and 3.
ii) Fines (passing 75 microns) : 3% to 10%.
iii) Los Angeles Abrasion value < 40%.

In exceptional cases on technical and economic considerations, LAA value may be relaxed upto 45% by CTE on Open Line & by CAO/C in construction projects.

Table-1 : Grading Percentage of Blanket Material

SL	IS Sieve Size	**Percent Passing** (by weight)
1.	40 mm	100
2.	20 mm	80 - 100
3.	10 mm	65 - 85
4.	4.75 mm	40 - 70
5.	2 mm	25 - 50
6.	600 micron	12 - 35
7.	425 micron	10 - 30
8.	212 micron	5 - 22
9.	75 micron	3 - 10

9.2 Blanket material should satisfy filter criteria in respect of sub-grade soil, which is to be protected to avoid upward migration of sub-grade soil causing fouling of ballast. Both UIC Railways and AREMA also specify the **filter criteria requirements**. The two resulting separation gradations for drainage filter criteria are :

- Criteria−1 : D_{15} (filter blanket) < 5 x D_{85} (sub-grade)
- Criteria−2 : D_{15} (filter) > 4 to 5 D_{15} (sub-grade)
- Criteria−3 : D_{50} (filter blanket) < 25 x D_{50} (sub-grade)

Criteria−1 causes particles at the coarsest end of the protected soil (D_{85}) to be blocked by particles at the finest end of the filter (D_{15}).

Criteria−2 is an additional criteria to ensure adequate permeability to drain sub-grade.

Criteria−3 is only a suggestive provision which helps to avoid gap-graded filters and create a filter gradation that is somewhat parallel to that of protected soil. It may be relaxed in exceptional cases by CTE on Open Line & by CAO/C in construction projects on technical and economic considerations.

10.0 SPECIFICATIONS OF GEO-TEXTILE TO BE USED BELOW BLANKET LAYER

10.1 Woven Geo-textile :

The Woven Geo-textile shall be of woven polypropylene multifilament type geotextile. The individual multifilament yarns are woven together into a stable fabric structure with a superior combination of mechanical and hydraulic properties. The product shall have excellent resistance to biological and chemical environments normally found in soils and shall be stable against short-term exposure to ultraviolet radiation.

The Woven Geo-textile shall be suitable for applications involving functions of separation, stabilization and filtration. The Woven Geo-textile shall conform to the property values listed below :

SL	Property		Test Method	Value (MARV)
I	Polymer Composition, Structure and Physical Properties			
1	Polymer		Polypropylene	
2	Structure		Woven with multifilament yarn in both warp and weft directions	
3	Mass per Unit Area		ASTM D 3776	240 g/m^2
II	Mechanical Properties			
1	Tensile Strength	Warp	IS : 1969	55 kN/m
		Weft		42 kN/m
2	Elongation at Designated Peak Tensile Load	Warp		20 %
		Weft		20 %
3	Trapezoid Tearing Strength	Warp	ASTM D 4533	1100 N
		Weft		750 N
4	Puncture Strength		ASTM D 4833	600 N
III	Hydraulic Properties			
1	Apparent opening size		ASTM D 4751	150 microns
2	Water Flow Rate Normal To The Plane		ASTM D 4491	32 l/m^2/s

1. Values listed are minimum average roll values except for II-2 and III-1, which are maximum average roll values.
2. The elongations reported are the actual fabric elongations at the designated peak tensile load measured over a gauge length of 100 mm.
3. The manufacturer shall submit certificate for all parameters specified for polypropylene multifilament woven geo-textile for every batch of 5000 sqm polypropylene multifilament woven geo-textile to be supplied and used at site.

10.2 Non-Woven Geo-textile :

(Ref : State-of-the-Art Report on Use of Geo-textile on Indian Railways, 1995) :

The geo-textile shall be of non-woven mechanically bonded type comprising 100% polypropylene continuous fibres. Geo-textile manufactured from staple (short) fibres or heat bonded shall not be used. The geo-textile shall have a high level UV stabilization. All requirements concerning UV-resistance, oxidation, hydrolysis, chemical resistance microbiological resistance and environmental compatibility have to be met as per relevant IS/European Norms.

(1)	Composition	:	Polypropylene
(2)	Mode of manufacture	:	Non-Woven, Needle punched
(3)	Thickness of fabric	:	2.5 mm at 2 kPa
(4)	Water permeability	:	More than that of the soil to be drained
(5)	Weight	:	300 gm/m^2 and above
(6)	Elongation at break	:	40% to 70%
(7)	Tensile strength	:	20 kN/m (minimum)
(8)	Pore size	:	120 Micron
(9)	Equivalent opening	:	40 to 75 micron size (EOS) 90°
(10)	Thermal stability	:	0°C to 100°C
(11)	Roll width	:	4.5 m for BG single line
(12)	Roll length	:	As per site requirement to suit workability with minimum joints.

10.3 These specifications are only suggestive in nature and final Standardised Specifications of geo-textile will be finalised & issued by RDSO subsequently after more studies and field visits etc.

11.0 SPECIFICATIONS OF GEO-GRID TO BE USED BELOW BALLAST LAYER

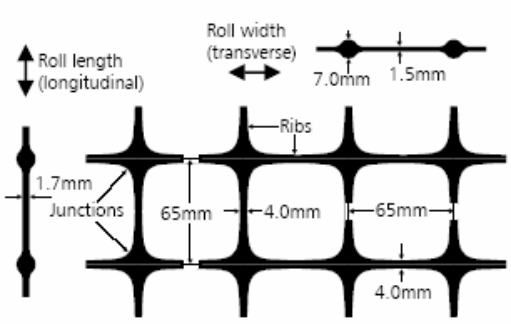
(Ref : Report of Vijayawada Division of South Central Railway for Formation Treatment)

11.1 The reinforcing element shall be a geo-grid manufactured in accordance with a Quality Management System which complies with the requirements of BS EN ISO 9001:2000. The Contractor/Supplier/Vendor shall provide evidence that the manufacturer's Quality Assurance System has been certified to conform with BS EN ISO 9001:2000 by an external authenticating authority.

11.2 The reinforcing element shall be a geogrid manufactured from polypropylene sheet, oriented in two directions so that the resulting ribs shall have a high degree of molecular orientation, which continues through the area of integral node.

11.3 The ribs of reinforcing element shall be of rectangular cross section in both longitudinal and transverse directions with a typical minimum rib thickness of 1.5mm. Geo-grid aperture size shall be approximately 61mm x 61 mm.

11.4 The typical strength of the nodes between the longitudinal and transverse ribs, shall be not less than 95% of the Quality Control Strength in both longitudinal and 'transverse directions.



11.5 Reinforcing element shall be inert to all chemicals naturally found in soils and shall have no solvents at ambient temperature. It shall not be susceptible to hydrolysis, shall be resistant to aqueous solutions of salts, acids and alkalis, shall be non-biodegradable and shall have a minimum of 2% finely divided carbon black, as determined by BS 27S2:Part 4: Method 452B:1993, well dispersed in the polymer matrix to inhibit attack by ultra violet light.

11.6 Technical Specifications :

Parameter/Description	Unit	Limits
Polymer (1)	-	PP
Minimum Carbon Black (2)	%	2
Roll Width	in	3.80
Roll Length	m	50
1 Unit Weight	Kg/Sqm	0.33
Roll Weight	Kg	65
Quality Control Strength Longitudinal -		
Tult (3)	KN/m	30
Load At 2% Strain (3)	KN/m	11
Load At 5% Strain (3)	KN/m	22
Approx Strain At Tult	%	9
Junction Strength (4)	%	95
Quality Control Strength Transverse -		
Tult (3)	KN/m	30
Load At 2% Strain (2)	KN/m	12
Load At 5% Strain (3)	KN/m	25
Approx Strain At Tult	%	9
Junction Strength (4)	%	95

Notes :

1) PP denotes Polypropylene.
2) Carbon black inhibits attack by UV light. Determined in accordance with BS 2782 part 4 Method 452B : 1993.
3) Determined in accordance with BS EN ISO 10319 1996 and as a lower 95% confidence limit in accordance with ISO 2602:1980 (BS 2846 part 2 : 1981).
4) Determined in accordance with GRI test method GG2-87 and expressed as % of Quality Control Strength.
5) The Geo-grid shall be inert to all chemicals naturally found in soils and shall have no solvents at ambient temperature. It shall not be susceptible to hydrolysis and shall be resistant to aqueous solutions of salts, acids and alkalis and shall be non-biodegradable.
6) The Goe-grid shall be manufactured in accordance with a quality Management system which complies with the requirements to BS EN ISO 9001:2000.
7) All quoted dimensions and values are typical unless stated otherwise.

11.8 Specifications of Geo-synthetics will be revised from time to time by G. E. Directorate of RDSO in terms of technological advancements/research/experience on the subject and also based on adoption of the products by various world railways alongwith their suitability for Indian conditions.

11.9 Vendors for all geo-synthetics items (geo-textiles & geo-grid etc.) will be developed and approved by RDSO. Subsequently, Zonal Railways will be procuring these items based on specifications & vendor list issued/approved by G. E. Directorate of RDSO.

12.0 OTHER IMPORTANT ASPECTS OF FORMATION DESIGN

Other than blanket thickness & specifications, general design and construction provisions for construction of stable formation have been given in 'Guidelines for Earthwork in Railway Projects, No. GE : G-1, July 2003'. For quick reference, following summarised important points should be kept in mind while planning & executing the construction work :

12.1 For banks higher than 6 metres, suitable slope stability analysis, reinforcement of slopes, plantation of deep root grass and toe wall construction shall be suitably adopted.

12.2 For base-soil/sub-strata with low bearing capacity (< 75 kPa), strengthening of sub-strata shall be carried out with suitable techniques, like replacement of clayey soil with sand, provision of stone columns, geo-grid layers and lime/cement grouting.

12.3 Soft sub-soil strata having undrained cohesion (Cu) < 25kPa or N-value (determined from Standard Penetration Test) < 4 will require ground improvement before construction of embankment. Embankment may require to be constructed in stages with adequate waiting period giving due allowance for consolidation of soft sub-soil. Preloading technique or provision of Vertical Sand Drains or PVC drains may be provided for fast & complete consolidation of soft compressible strata.

12.4 Poor soils, i.e. soils having CBR < 4, organic soils, CH & MH type of soils should not be used for construction of embankment.

12.5 In case of high bank on soft sub-soil, flatter slope with berm/sub-bank should be provided after slope stability analysis.

12.6 Adequate drainage arrangement should be made by providing cross slope at top of formation and side drains/catch water drains, wherever required.

12.7 Adequate erosion control measures on slopes of bank & cutting should be ensured by vegetation on slopes with deep-rooted Vetiver grass & geo-jute textile, if necessary.

12.8 Adequate compaction should be ensured in each layer of earthwork & blanket, as specified in RDSO's 'Guidelines of Earthwork in Railway Projects-July 2003'. For good quality formation, minimum value of Deformation Modulus EV_2 of 120 MPa (measured by second loading in Plate Load Test) should be ensured at top of blanket layer.

12.9 At locations, where the water table is high and the fill soil is fine-grained, it may be desirable to provide a granular layer of about 30 cm thickness at the base, above sub-soil across the full width of formation.

12.10 Sandwich type of construction may be adopted for construction of embankments with cohesive soils having very low permeability (less than 10^{-2} cm/sec) and where height of bank is greater than 3m. In such situations, a layer of coarse sand (Cu>2) of about 20-30 cm thickness should be provided at bank height intervals of 2m to 3m.

12.11 Stable slopes and adequate drainage arrangements in cutting areas should be provided as per details given in 'Guidelines for Cutting in Railway Formations - No. GE : G-2, August 2005'.

12.12 For high banks at the approaches of rail bridges, providing approach slabs and geogrid layer shall be also considered and adopted.

12.13 In doubling & Gauge Conversion projects, new earthwork should be properly merged with existing formation after adequate benching over existing slopes.

12.14 **Reinforced Earth Construction** may be adopted wherever steep slope/vertical wall construction is required due to space constraint or otherwise. In this regard, RDSO's report on 'Concept and Design of Reinforced Earth Structures, No. GE-R-63, June 2005' should be consulted.

12.15 In order to have satisfactory performance of formations for very long duration and running of further heavier axle loads in future, it is advisable to **use geo-grid & geo-textile** in the top portion of formation. Provision of geo-grid at ballast & blanket interface can reduce blanket requirement by 30% keeping minimum blanket thickness of 15 cm. In case, fine-grained soils are used in top of sub-grade, a geo-textile should be provided at blanket & sub-grade interface.

12.16 **Formation Width :** Present standard width of formation of embankment is 6.85 m for single BG line. This appears to bare minimum taking ballast side slope of about 1H:1V and cess width of 90 cm. Present ballast side slope of 1H : 1V gets disturbed frequently by train vibrations and requires frequent maintenance to make it up to correct profile.

Some advanced Railway Systems (like AAR) adopt ballast side slope of 2H:1V and cess width of 120 cm (Japanese Railway). Cess width of 90 cm is also inadequate especially at high bank locations to move men, materials and machineries.

Therefore, it is desirable to increase standard formation width of BG embankment for new lines upto 8.5 m for ballast side slope of 2H:1V and cess width of 120cm

13.0 CONCLUSIONS AND RECOMMENDATIONS

13.1 Requirement of sub-structure layer between ballast & sub-grade for higher axle load & weak sub-grade is of the order of one metre or so. Provision of blanket layer with single material becomes many times costly, since blanket, being selected material, may be available at high cost. Similar to other advanced Railway Systems, two-layer concept of blanket has been recommended (Illustrations in Sketch-2 & Table-2), which will serve all the functional requirements as well as be economical due to saving in costly blanket material. Cost saving may be of the order of Rs. 25 lacs to 50 lacs per km of construction of embankment depending on cost of blanket material.

13.2.1 Geo-synthetics are already in use widely in leading Railway Systems world over. Use of Geo-synthetics in conjunction with blanket layer has been recommended to reduce blanket layer thickness alongwith serving all required functions effectively in case of sub-grade constructed using weak soils. With easy availability of geo-synthetics, its use will be purposeful and economical.

13.3 Thickness of blanket layer, as given in Table–2 and Sketch–C are recommended to be adopted for different Axle Loads, Speed, GMT & Soil Category. Specifications of blanket, Geo-grid & Geo-synthetics should be adopted as given in Para 9, 10 & 11. Other important aspects of formation design, e.g. formation width, side slope, drainage, sub-soil improvement etc. should also be given due importance.

13.4 This document supersedes all the previous instructions/guidelines related to thickness and specifications of blanket material. All other provisions in various Guidelines/ Specifications/Technical Reports issued by RDSO on other related subjects, as already circulated to Zonal Railways are available at RDSO website. These should be followed & adopted in order to construct stable track formation.

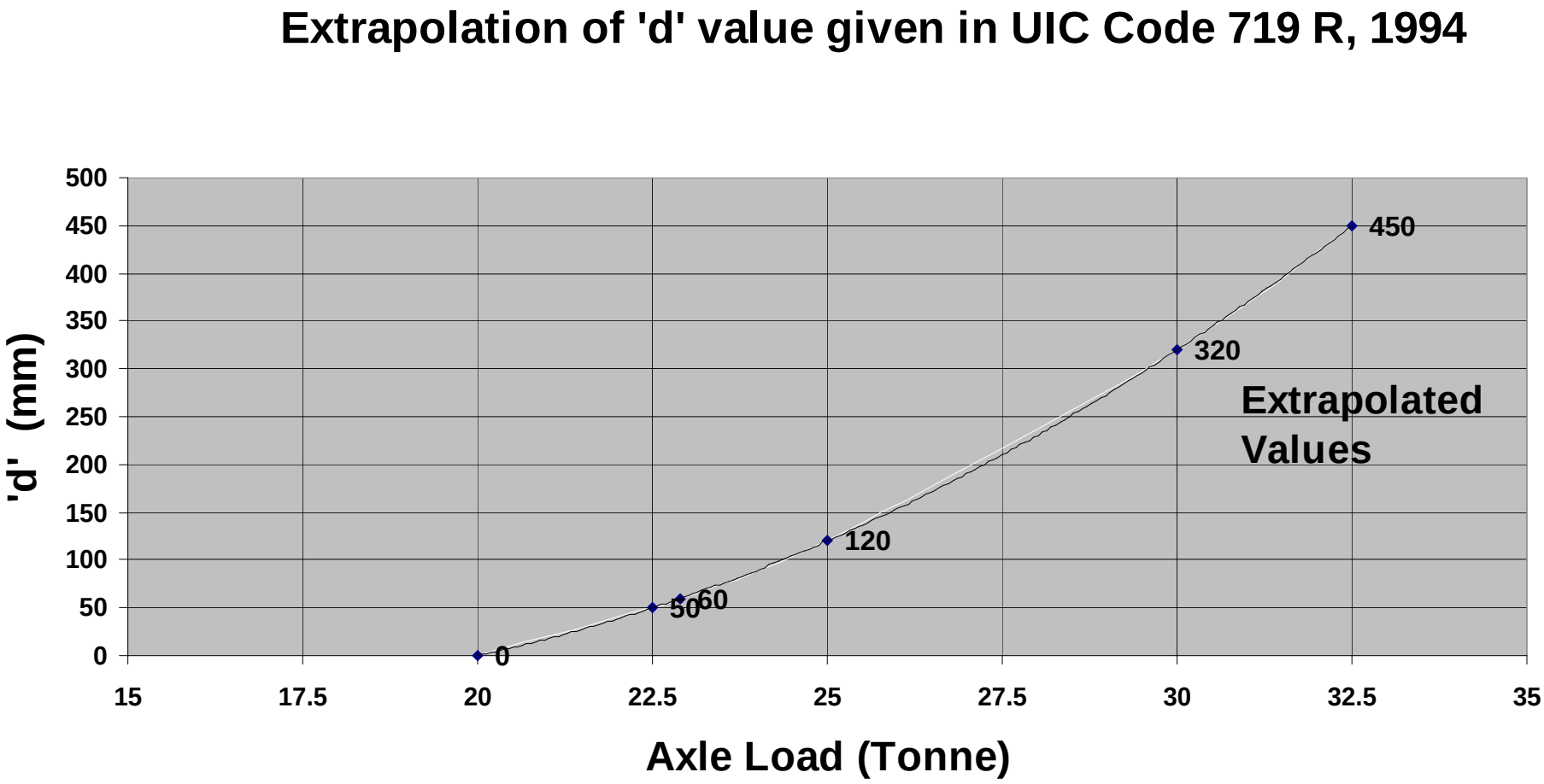
14.0 REFERENCES

(i) Guidelines of Earthwork in Railway Projects, no. GE:G-1, July,2003
(ii) State of the art report on sub grade stress and design of track substructure, Civil Engineering Report No. C – 271.
(iii) State Of The Art Report On Provision Of Railway Formation, Report No. GE – 35.
(iv) ORE Report D – 71, RP – 12.
(v) UIC Code 719 – 1994 R
(vi) UIC Code 714 – 1963 R
(vii) Procedure for Railway track granular layer thickness determination Report no. R-898, October-1996
(viii) AREMA Manual, 2002
(ix) Australian Railway (ARTC) Code RTS 3430, March 2006

ACKNOWLEDGEMENT

The Document has been prepared by the team of Geo-technical Engineering Directorate of RDSO, with special contributions from Shri M.K. Gupta, Director/GE, Shri S.K. Awasthi, ARE/GE and Shri S.K. Ojha, SSRE/GE, under the guidance of Shri Alok Kumar, Executive Director/GE. Drawing work has been done by Shri Sushil Kumar, JE-1(Design)/GE.

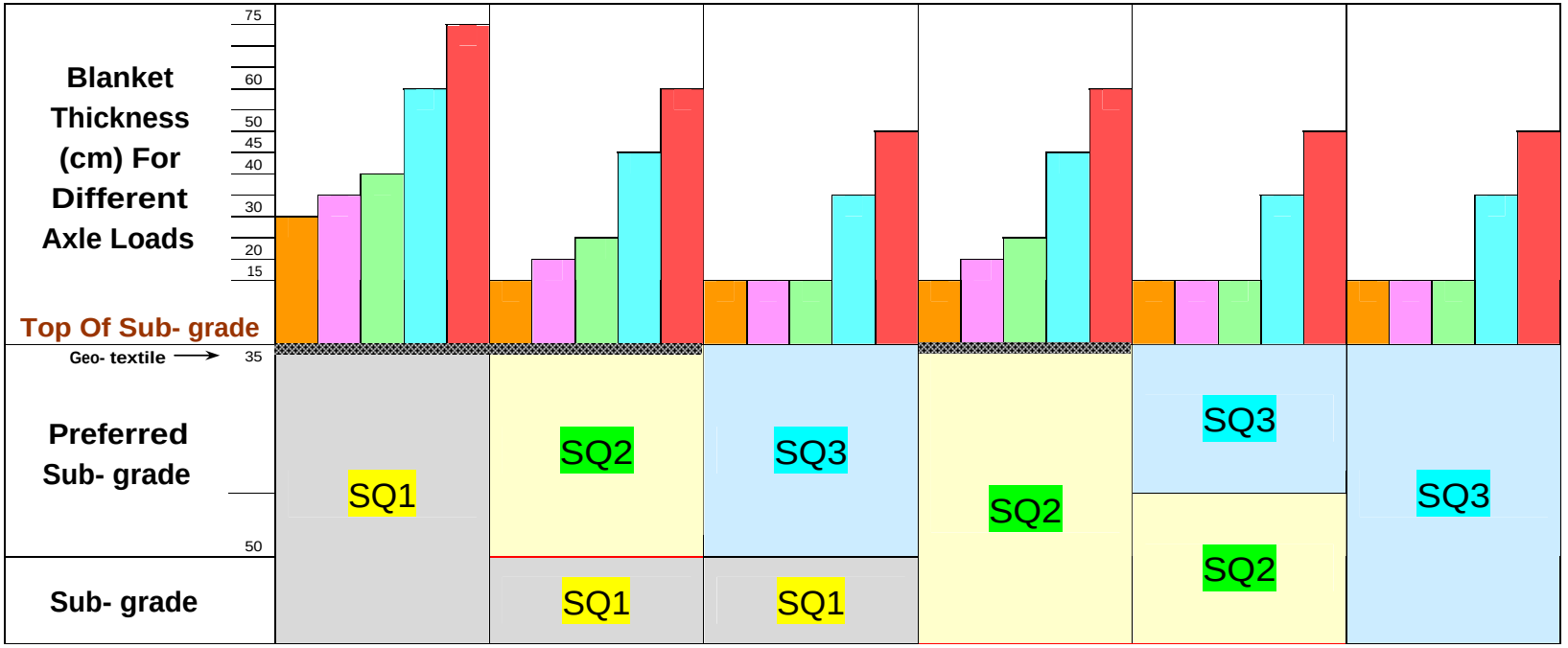
Sketch - 1


Extrapolation of 'd' value given in UIC Code 719 R, 1994
'd' (mm)
500
450
400
350
300
250
200
150
100
50
0
15
17.5
20
22.5
25
27.5
30
32.5
35
Axle Load (Tonne)
0
50
60
120
320
450
Extrapolated Values

Research Designs And Standards Organisation : Geo-technical Engineering Directorate **SKETCH - 2**

Two Layers System Of Formation Top : Thickness Of Blanket Material And Prepared Sub-Grade

For Different Soil-Quality Of Sub-Grade



Notes : 1. **Geo-textile** shall mandatorily be provided at bottom of blanket layer, if prepared sub-grade is made of SQ1 or SQ2 soils.
2. If **Geo-grid** is used below ballast layer, the recommended blanket thickness will be reduced by 30%, subject to minimum thickness of 15cm.
3. Soils having **CBR Value** less than 4 should not be used in sub-grade unless consulted with RDSO.

Categories Of Soil-Quality :

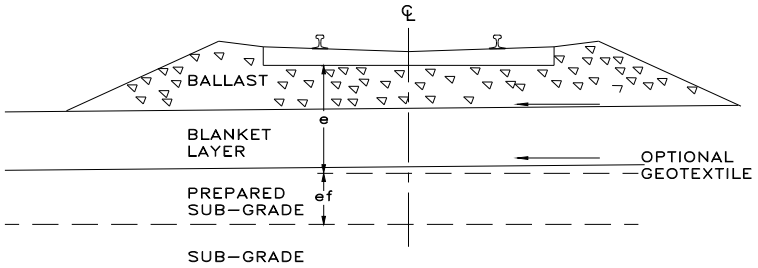
Soil Quality	Description w.r.t. Fine Particles (< 75 micron)
SQ1	Soils containing fines > 50 %
SQ2	Soils containing fines from 12% to 50%
SQ3	Soils containing fines < 12%

Axle Load	Colour Code For Blanket Thickness
20 T	
22.9 T (CC+8+2)	
25 T	
30 T	
32.5 T (For DFC)	

Table 2 - Proposed Two Layers System Of Blanketing On Track Formation For Adoption On Indian Railways

(Reference : Calculations based on UIC practices in terms of UIC Code 719R-1994)

SL	Soil Quality Category in Sub-grade used in embankment	Top Soil of Formation (prepared Subgrade)		Recommended Thickness (mm) of Blanket for Axle Loads :					Remarks
		Quality	Thickness (mm)	20 T	22.9 T (CC+8+2)	25 T	30T	32.5 T (For D.F.C.)	
1	SQ1	SQ1	-	300	350	400	600	750	Geo-synthetics to be used
2	SQ1	SQ2	500	150	200	250	450	600	Geo-synthetics to be used
3	SQ1	SQ3	500	150*	150*	150	350	500	Geo-synthetics is optional
4	SQ2	SQ2	-	150	200	250	450	600	Geo-synthetics to be used
5	SQ2	SQ3	350	150*	150*	150	350	500	Geo-synthetics is optional
6	SQ3	SQ3	-	150*	150*	150	350	500	Geo-synthetics is optional



Explanatory Notes :

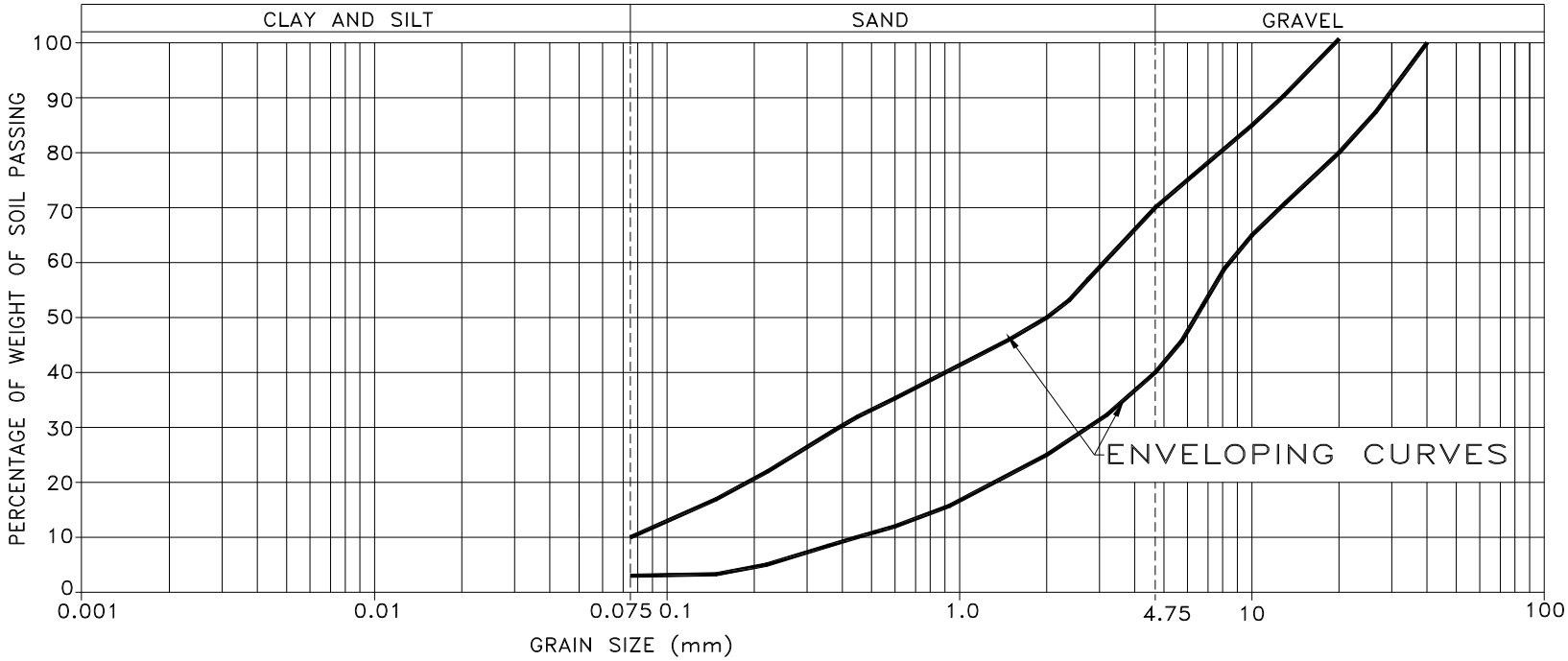
1. Categories Of Soil-Quality :

SL	Soil Quality	Description w.r.t. Fine-Particles (size less than 75 micron)	IS Classification Conforming to Referred Soil Quality (Suggestive)	CBR Value
1	SQ1	Soils containing fines > 50 %	CL, ML, CL-ML, CI, MI, CH, MH	Minimum CBR value of 4% should be ensured for soil to be used as sub-grade material.
2	SQ2 **	Soils containing fines from 12% to 50%	GM, GC, SM, SC	
3	SQ3 ***	Soils containing fines < 12%	GW, GP, SW, SP, GW-GM, GW-GC, SW-SM, GP-GM, GP-GC, SP-SM, SP-SC etc.	

* Theoretical requirement of blanket thickness is less than those recommended.
** These soils will come in SQ1 category, if hydrological or drainage conditions are not good.
*** Soils having fines in range of 5% – 12% will come in SQ2 category, if hydrological or drainage conditions are not good.

2. Recommended thickness of blanket material has been worked out with the provision of 300mm ballast cushion.
3. Recommended blanket thickness is suitable for GMT > 25 & Speed < 160 kmph.
4. Blanket thickness may be reduced by 5 cm for routes with GMT from 10 – 25 and by 10 cm for GMT < 10.
5. Blanket thickness may be increased by 5cm/10cm, if speed is more than 160 kmph and prepared sub-grade is of SQ2/SQ1 category soil.
6. In case of new construction, if SQ1 sub-grade is used for embankment construction, preferably SQ3/SQ2 category of soils should be used at top of formation.
7. In case, it is unavoidable to use soil having CBR value less than 4 for construction of formation, RDSO should be consulted.
8. Geo-synthetics (Geo-grid & Geo-textile) :
   (i) Geo-textile should be provided below blanket layer, if soil of category SQ1/SQ2 is used in prepared sub-grade.
   (ii) Provision of geo-grid below ballast can reduce thickness of blanket layer by 30%. However, minimum 15 cm thickness of blanket should be ensured.
   (iii) Specifications of Geo-synthetics may be revised from time to time by G. E. Directorate of RDSO in terms of technological advancements/ research on the subject and also based on adoption of the products by various world railways alongwith their suitability for Indian conditions.

SKETCH–3



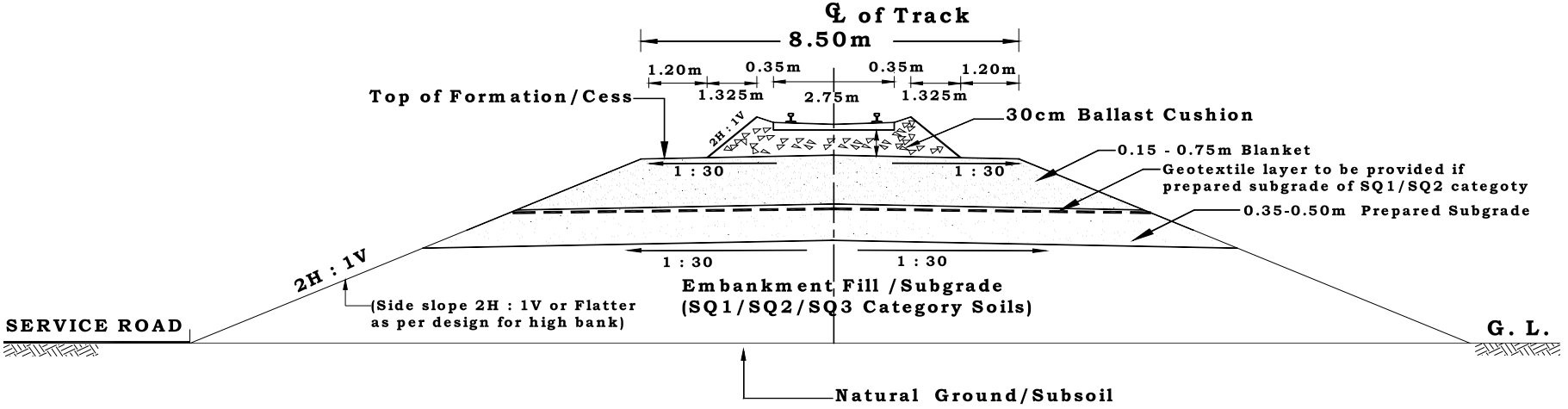
SPECIFICATIONS:

1. THE BLANKET MATERIAL SHOULD BE COARSE, GRANULAR AND WELL GRADED.
2. SKIP GRADED MATERIAL IS NOT PERMITTED.
3. PARTICLES FINER THAN 75 MICRONS SHOULD BE PERMITTED IN RANGE OF 3 TO 10%.
4. UNIFORMITY COEFFICIENT (D_{60}/D_{10}), SHOULD BE MORE THAN 7.
5. THE COEFFICIENT OF CURVATURE ($D_{30}^2 / D_{60} . D_{10}$), TO BE WITHIN 1 & 3.
6. THE PARTICLE SIZE GRADATION CURVE SHOULD LIE MORE OR LESS WITHIN GUIDING ENVELOPING CURVES.
7. LOS ANGLES ABRSION VALUE SHOULD NOT BE MORE THAN 40.
8. FILTER CRITERIA W.R.T. SUBGRADE SHOULD BE SATISFIED AS GIVEN IN PARA 9.2.

R. D. S. O.

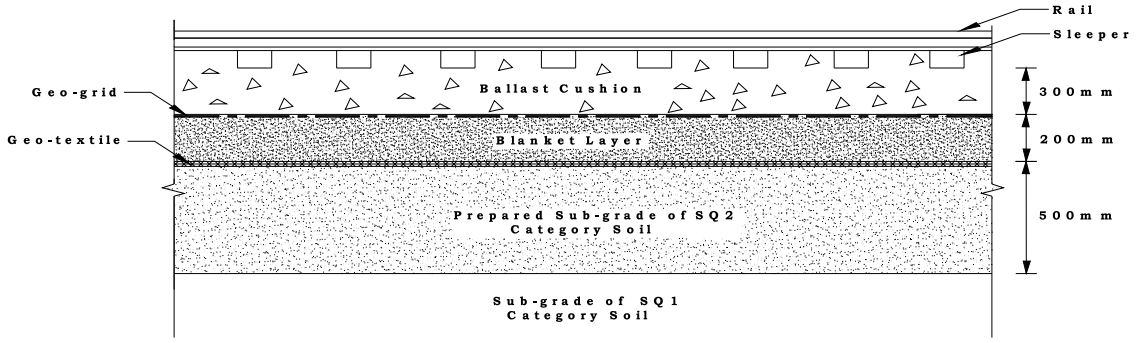
ENVELOPING CURVES
FOR
BLANKET MATERIAL

SKETCH - 4



Typical Cross-Section of Track Formation For Heavy Axle Load Freight Corridor For Different Soil-Categories In Sub-grade & Prepared Sub-grade

(Reference : Sketch-2 And Table-2 At Pages 20 & 21)



Typical Longitudinal-Section of Track Formation For 25T Axle Load

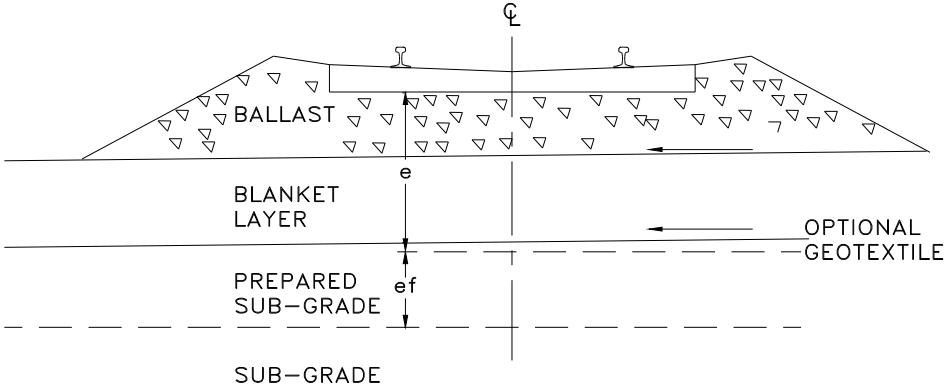
Note : Depth of blanket layer has been reduced from 250 mm to 200 mm due to provision of Geo-grid.

Annexure – 1

Calculation of Blanket Thickness of Different Combinations for Axle Load, Speed, GMT and Soil Type as per UIC Code 719R, 1994 *(Please Refer Para 5.1 above)*

Minimum thickness (e) of track bed layers including ballast & blanket is -

e = E + a + b + c + d + f + g as explained in figure below :



Where,

E = 0.70 m	For SQ1 **soils used as prepared sub-grade**
E = 0.55 m	For SQ2 soils used as prepared sub-grade
E = 0.45 m	For SQ3 soils used as prepared sub-grade

(Thickness of prepared sub-grade varies from 35 cm to 50 cm)

a = 0	For **UIC groups** 1 & 2# (or lines where speed>160 km for all UIC groups)
a = -0.05m	For UIC group 3 & 4
a = -0.10m	For UIC groups 5, 6 & 7, 8, 9 with passengers
a = -0.15m	For UIC groups 7, 8, 9 without passengers

b = 0	For wooden **sleepers of length** 2.60m
b = (2.50-L) / 2	For concrete sleepers of length L (b in m, L in m) = (2.50-2.75)/2 = 0.125 m, For PSC Sleeper of 2.75m length on IR

c = -0.05 m	For difficult **working condition**

d = 0 For 200 kN **axle load**
d = 0.05 m For 225 kN axle load
d = 0.12 m For 250 kN axle load

f = 0 For **speed** < 160 kmph
f = 0.05 m For speed > 160 kmph for sub-grade of SQ2 class
f = 0.10 m For speed > 160 kmph for sub-grade of SQ1 class

g = + Track bed must include a **geo-textile** for soil of SQ1 & SQ2 class

Based on above values of various factors, blanket thickness calculated and recommended for different axle loads and combinations of soil category used in embankment & prepared Sub-grade has been worked out in following table :

SL	**Axle Load** (Tonne)	**Soil Category Used In Embankment**	**Soil Category used in Prepared Sub-grade**	**Thickness Of Prepared Sub-grade** (mm)	**E** (mm)	**a** (mm)	**b** (mm)	**c** (mm)	**d** (mm)	**f** (mm)	**g** (Geo-textile)	**Total Thickness Of Ballast & Blanket 'e'** (from above formula) (mm)	**Ballast Depth** (mm)	**Calculated Blanket Thickness** (mm)	**Recommended Blanket Thickness *** (mm)
1.	**20.32**	**SQ1**	**SQ1**	**-**	700	0	- 125	0	0	0	+	**575**	300	275	**300**
		SQ1	**SQ2**	**500**	550	0	- 125	0	0	0	+	**425**	300	125	**150**
		SQ1	**SQ3**	**500**	450	0	- 125	0	0	0	0	**325**	300	25	**150**
		SQ2	**SQ2**	**-**	550	0	- 125	0	0	0	+	**425**	300	125	**150**
		SQ2	**SQ3**	**350**	450	0	- 125	0	0	0	0	**325**	300	25	**150**
		SQ3	**SQ3**	**-**	450	0	- 125	0	0	0	0	**325**	300	25	**150**
2.	**22.9 (CC+8+2)**	**SQ1**	**SQ1**	**-**	700	0	- 125	0	60	0	+	**635**	300	335	**350**
		SQ1	**SQ2**	**500**	550	0	- 125	0	60	0	+	**485**	300	185	**200**
		SQ1	**SQ3**	**500**	450	0	- 125	0	60	0	0	**385**	300	85	**150**
		SQ2	**SQ2**	**-**	550	0	- 125	0	60	0	+	**485**	300	185	**200**
		SQ2	**SQ3**	**350**	450	0	- 125	0	60	0	0	**385**	300	85	**150**
		SQ3	**SQ3**	**-**	450	0	- 125	0	60	0	0	**385**	300	85	**150**

3.	**25**	**SQ1**	**SQ1**	**-**	700	0	- 125	0	120	0	+	**695**	300	395	**400**
		SQ1	**SQ2**	**500**	550	0	- 125	0	120	0	+	**545**	300	245	**250**
		SQ1	**SQ3**	**500**	450	0	- 125	0	120	0	0	**445**	300	145	**150**
		SQ2	**SQ2**	**-**	550	0	- 125	0	120	0	+	**545**	300	245	**250**
		SQ2	**SQ3**	**350**	450	0	- 125	0	120	0	0	**445**	300	145	**150**
		SQ3	**SQ3**	**-**	450	0	- 125	0	120	0	0	**445**	300	145	**150**
4.	**30**	**SQ1**	**SQ1**	**-**	700	0	- 125	0	320	0	+	**895**	300	595	**600**
		SQ1	**SQ2**	**500**	550	0	- 125	0	320	0	+	**745**	300	445	**450**
		SQ1	**SQ3**	**500**	450	0	- 125	0	320	0	0	**645**	300	345	**350**
		SQ2	**SQ2**	**-**	550	0	- 125	0	320	0	+	**745**	300	445	**450**
		SQ2	**SQ3**	**350**	450	0	- 125	0	320	0	0	**645**	300	345	**350**
		SQ3	**SQ3**	**-**	450	0	- 125	0	320	0	0	**645**	300	345	**350**
5.	**32.5 (DFC)**	**SQ1**	**SQ1**	**-**	700	0	- 125	0	450	0	+	**1025**	300	725	**750**
		SQ1	**SQ2**	**500**	550	0	- 125	0	450	0	+	**875**	300	575	**600**
		SQ1	**SQ3**	**500**	450	0	- 125	0	450	0	0	**775**	300	475	**500**
		SQ2	**SQ2**	**-**	550	0	- 125	0	450	0	+	**875**	300	575	**600**
		SQ2	**SQ3**	**350**	450	0	- 125	0	450	0	0	**775**	300	475	**500**
		SQ3	**SQ3**	**-**	450	0	- 125	0	450	0	0	**775**	300	475	**500**

* 1. Recommended blanket thickness is suitable for GMT > 25 & Speed < 160 kmph.
2. Blanket thickness may be reduced by 5 cm for routes with GMT from 10 to 25 and by 10 cm for GMT < 10.
3. Blanket thickness may be increased by 5 to 10 cm, if speed is more than 160 kmph and prepared sub-grade of SQ2/SQ1 category soil.

\# As per UIC 714, UIC Group of lines or sections is depending on theoretical load in daily gross tonnage The details & equivalents on IR are as under :

UIC Groups	**t/day**	**Equivalent GMT As Per IR Practices**
Group 1	T_f > 102,000 t/day	> 37.23 GMT
Group 2	102,000 > T_f > 70,000	37.23 > T > 25.55
Group 3	70,000 > T_f > 40,000	25.55 > T > 14.60
Group 4	40,000 > T_f > 25,000	14.60 > T > 9.13
Group 5	25,000 > T_f > 12,500	9.13 > T > 4.56
Group 6	12,500 > T_f > 6,000	4.56 > T > 2.19
Group 7	6,000 > T_f > 3,000	2.19 > T > 1.1
Group 8	3,000 > T_f > 1,000	1.1 > T > 0.36
Group 9	1,000 > T_f	0.36 > T